

2025 NCTS Student Workshop on Scientific Computing

A TV-L2 Variational Model for Robust Optical Flow Estimation Under Inhomogeneous Illumination

Ku-Te Lin (National Central University)

Abstract:

Optical flow estimation is a fundamental problem in computer vision, aiming to quantify the motion of objects between consecutive frames in an image sequence. Optical flow is typically represented as a vector field, where each vector captures the displacement of a pixel from one frame to the next. Traditional approaches often rely on the brightness constancy assumption, which posits that the intensity of a pixel remains unchanged over time as it moves. However, this assumption frequently fails under inhomogeneous illumination conditions, where lighting variations can significantly degrade estimation accuracy. In this talk, we present a novel TV-L2 variational model designed to address the challenges of optical flow estimation under inhomogeneous illumination. Our model integrates total variation (TV) regularization to preserve motion boundaries and an L2 data fidelity term to handle illumination variations. We propose an iterative split Bregman scheme to solve the associated optimization problem efficiently, ensuring robustness and computational efficiency. Through extensive numerical experiments, we demonstrate the effectiveness and efficiency of our proposed model, showcasing its superior performance in handling complex illumination scenarios compared to traditional methods.

An Introduction to the Mathematics of Score-Based Generative Models

Chan-Jung Hsu (National Central University)

Abstract:

Nowadays, generative models have become very popular. Among them, diffusion models are the most well-known for their ability to generate high-quality images from noisy ones. Score-Based Generative Models, a type of diffusion model, consist of two main processes: the forward process

$$\begin{cases} d\mathbf{x} = \mathbf{f}(\mathbf{x}, t)dt + \mathbf{G}(\mathbf{x}, t)d\mathbf{W}_t, \\ \mathbf{x}(0) \sim p(\mathbf{x}(0)), \end{cases}$$

and backward process

$$\begin{cases} d\bar{\mathbf{x}}(t) = (\mathbf{f}(\bar{\mathbf{x}}, t) - (\mathbf{G}\mathbf{G}^T)(\bar{\mathbf{x}}, t)\nabla_{\mathbf{x}} \log p(\bar{\mathbf{x}}, t))dt + \mathbf{G}(\bar{\mathbf{x}}, t)d\mathbf{W}_t, \\ \bar{\mathbf{x}}(T) \sim p(\bar{\mathbf{x}}(T)), \end{cases}$$

where $\mathbf{x}$ and $\bar{\mathbf{x}}$ are images at time $t \in [0, T]$, $\mathbf{f}$ is the drift term, $\mathbf{G}$ is the diffusion term, and $\mathbf{W}_t$ is the Wiener process. In the forward process, we gradually add noise to the original images. The goal is for the neural network to learn the structure of this noise. Then, in the backward process, the trained neural network denoises the images, effectively reconstructing the original images from their noisy versions.

In this talk, I will introduce the mathematical concepts behind score-based generative models and explain the role of the neural network within these models. The presentation only requires an undergraduate-level understanding of calculus and probability theory.

Efficient Sampling Strategies for Diffusion Models

Bi-Cheng Gu (National Yang Ming Chiao Tung University)

Abstract:

Diffusion models have demonstrated impressive performance in generative tasks, but their sampling process remains slow due to the large number of iterative steps required. In this work, we tackle this inefficiency from the perspective of Score-based SDEs, and introduce techniques

that integrate traditional ODE methods to accelerate sampling without compromising sample quality. We evaluate our approach on the CIFAR-10 dataset using the Fréchet Inception Distance (FID) score, and show that our method effectively speeds up the sampling process while maintaining high-quality generation.

Stretch Energy Minimization Applied to Area-Preserving Mapping of Point Clouds

Tzu-Ching Liang (National Taiwan Normal University)

Abstract:

This presentation explores the application of Stretch Energy Minimization (SEM) to achieve area-preserving parameterization of point clouds. We begin by introducing the concept and sources of point clouds, including phase-based and pulse-based distance measurement techniques. The method proceeds by constructing local patches using k-nearest neighbors, defining vertex rings, and applying Principal Component Analysis (PCA) to derive local tangent planes. Based on these, we perform Delaunay triangulation and compute the cotangent Laplacian to extract geometric features.

The SEM method, grounded in the theoretical framework of minimizing stretch energy over simplicial surfaces, aims to achieve mappings that preserve area while ensuring geometric consistency. The process involves defining a stretch energy functional and solving an optimization problem to minimize this energy.

Finally, numerical experiments are conducted using MATLAB on both open and closed surface point cloud models, including Nefertiti, ChineseLion, David, and Bunny. Results show that SEM effectively maintains point density and area consistency across various geometries. This work holds practical significance in point cloud processing, geometric modeling, and scientific computing.

Classification of CDKN2A/B Homozygous Deletion in Brain Tumors Using Optimal Mass Transport, Deep Learning Segmentation, and Radiomics

Hung-Yang Lin (National Taiwan Normal University)

Abstract:

This study focuses on preprocessing imbalanced Dynamic Contrast-Enhanced MRI (DCE-MRI) data, extracting radiomic features, and employing machine learning models to classify CDKN2A/B homozygous deletion in brain tumors.

First, the Optimal Mass Transport (OMT) method is applied to downsample the original DCE-MRI images from $256 \times 220 \times 176$ to $128 \times 128 \times 128$, reducing computational costs and storage requirements. Then, the nnUNet model, trained on the BraTS dataset, is employed for automatic brain tumor segmentation, labeling the tumor regions.

Radiomics features are extracted from the labeled Whole Tumor (WT) region, followed by feature selection and dimensionality reduction using independent samples t-tests and LASSO regression to enhance model performance and interpretability. Subsequently, Support Vector Machine (SVM) and Logistic Regression classifiers are constructed, with their performance evaluated using ROC-AUC and recall metrics. Finally, SHapley Additive exPlanations (SHAP) is employed to analyze the contribution of radiomics features to model decisions.

Neural Network with Discontinuous Architecture

Tan Wang (National Cheng Kung University)

Abstract:

Neural networks effectively approximate continuous functions but face significant challenges with discontinuous phenomena. This presentation discusses specialized neural network architectures designed for discontinuities. We highlight how these methods achieve superior accuracy and efficiency in modeling functions with jumps or abrupt transitions. Practical examples and

theoretical insights demonstrate their advantages over conventional neural networks, underscoring future research directions and unresolved challenges in the field.

Single-Image Inpainting via Sparse Representation and Color-Vectorized Dictionary Learning

Tai-Hua Lee (National Chung Hsing University)

Abstract:

In the past, image inpainting algorithms often encountered issues such as image blurring and color deviation when handling large-area inpainting tasks. To address these deficiencies and improve computational efficiency, in this talk we will introduce a novel color image inpainting method based on sparse representation and color-vectorized dictionary learning. This method vertically concatenates the three color channels from known patches in the image to be inpainted into column vectors, ensuring that the proportions between the three channels remain undisturbed, thereby reducing the occurrence of color deviation. First, we apply divide-and-conquer computation to color-vectorized dictionary learning, which reduces training time costs and enhances dictionary adaptability, thereby training a feature dictionary from the known regions that can represent image patches. Next, we utilize this feature dictionary to compute sparse representations, inferring patches most similar to the original image. Finally, we fill the computed patches into the missing regions to complete the image inpainting. Experimental results demonstrate that the proposed method effectively improves upon common blurring and color deviation issues in traditional inpainting methods, enhancing inpainting quality.

Image Segmentation for Parasite Classification

Yi-Ru Chen (National Tsing Hua University)

Abstract:

With the increasing number of migrant workers in Taiwan, fecal parasite screening has become a critical task in public health. Manual inspection is labor-intensive and time-consuming, creating a demand for automated solutions. In this study, we present an integrated pipeline that combines image segmentation and classification for parasite detection.

We employ a Mask R-CNN model to segment parasite eggs from microscopic images, using their nuclear arrangement patterns as a key visual cue. A subsequent classification algorithm is applied to categorize the segmented eggs by species. This task is particularly challenging due to blurry image quality and severe class imbalance among parasite types. Despite these difficulties, our approach achieves an overall classification accuracy of approximately 80%, demonstrating strong potential for real-world deployment in high-throughput screening workflows.

Optimal Control Design for Nonlinear Systems Using State-Dependent and Riccati Equation Methods

Chung An Chen (National Chengchi University)

Abstract:

This talk investigates the design of optimal controllers for nonlinear dynamic systems by introducing two distinct approaches: the linearization method and the state-dependent method. The central idea is to use the Riccati differential equation (RDE) and the continuous algebraic Riccati equation (CARE) to compute the feedback gain matrix K such that the controller $u = -Kx$ ensures closed-loop stability while minimizing a predefined quadratic cost function. An inverted pendulum on a cart is utilized as a case study to compare the performance of both approaches. Simulation results indicate that although the linearization method performs well under small disturbances, the state-dependent method offers enhanced control precision when the initial state deviates significantly from equilibrium.

Solving the Poisson Equation via a Hybrid Approach of PINNs and ADMM

Wei Yuan Hsiao (National Yang Ming Chiao Tung University)

Abstract:

We propose a hybrid method for solving the Poisson equation by combining Physics-Informed Neural Networks (PINNs) with the Alternating Direction Method of Multipliers (ADMM). PINNs are first employed to generate an initial guess on a structured grid, leveraging their ability to approximate PDE solutions without the need for mesh refinement. This initial estimate is then refined through a variational formulation solved by ADMM, which decomposes the problem into direction-wise Poisson subproblems. While our current implementation demonstrates promising results on fine grids, we are conducting ongoing experiments to assess whether this hybrid approach can retain its accuracy and convergence efficiency on coarser and medium-resolution grids. The method is particularly appealing for high-dimensional problems, where traditional solvers face challenges in scalability.

Unravelling the Mysteries of Sounds in Magdalena Valley

Chu-Ping Hsiao (National University of Kaohsiung)

Abstract:

This study focuses on applying deep learning to bird sound recognition, using audio data collected from the Magdalena Valley in Colombia, a tropical region known for its rich biodiversity. Due to the noisy nature, we performed data cleaning and segmentation on the raw audio data and converted the recordings into Mel spectrograms, which serve as the inputs for the model. The Mel spectrogram is a frequency representation that mimics human auditory perception, effectively capturing the energy distribution of bird calls across time and frequency. This transformation plays a crucial role in extracting detailed acoustic features from bird sounds. By visualizing the audio in this way, the data becomes interpretable by deep learning models. We then trained a classifier using EfficientNetB2, and the preliminary results show good recognition performance across most bird species. Overall, this workflow—from raw sound to spectrogram—establishes a vital bridge for sound-based species identification.

Quantum Channel Search

Su-Yi Chen (National Cheng Kung University)

Abstract:

Designing a quantum channel represented by an orthogonal transformation to implement a specific input-output state mapping presents a significant challenge due to the inherent structural constraints. Given a single pair of input-output quantum states, the objective is to identify an orthogonal matrix that transforms the input to best approximate the given output. To address this, we propose a continuous-time optimization framework based on projected gradient flow, preserving the orthogonality constraint throughout the optimization process. This method offers an efficient approach to solving the constrained optimization problem under orthogonality constraints.

Index Search for Solving Least-Squares Problems from Adaptive Variational Models in Low-Light Image Enhancement

Chang-En Du (National Yang Ming Chiao Tung University)

Abstract:

We discretize an adaptive variational model for contrast enhancement of low-light images and reformulate it as a least-squares problem. An index search method is then employed to solve the resulting optimization problem efficiently. A series of numerical experiments are conducted to examine the impact of parameter choices on image quality. Furthermore, comparisons with the Operator Splitting Quadratic Program (OSQP) solver are provided to demonstrate the effectiveness and efficiency of the proposed approach.